LCA Case Studies

LCA of Concrete and Steel Building Frames

Åsa Jönsson, Thomas Björklund, Anne-Marie Tillman

Technical Environmental Planning, Chalmers University of Technology, S-412 96 Göteborg, Sweden

Corresponding author: M.Sc. Åsa Jönsson (e-mail: asaj@vsect.chalmers.se)

Abstract

The effects on the external environment of seven concrete and steel building frames representative of present-day building technology in Sweden were analysed using LCA methodology. Objects of the study included frame construction and supplementary materials. Several-storey offices and dwellings were studied. The functional unit was defined as one average m^2 of floor area during the lifetime of the building. Inventory data were elaborated for concrete and steel production, the building site, service life, demolition and final disposal. Parameters included were raw material use, energy use, emissions to air, emissions to water and waste generation. The inventory results were presented and evaluated as such, in addition to an interpretation by using three quantitative impact assessment methods. Parameters that weighed heavily were use of fossil fuels, CO_2, electricity, SO_x, NO_x, alloy materials and waste, depending on what assessment method was used. Over the life cycle, building production from cradle to gate accounted for about the same contribution to total environmental loads as maintenance and replacement of heat losses through external walls during service life, whereas demolition and final disposal accounted for a considerably lower contribution.

Keywords: Building frames; buildings; case studies; concrete; LCA; Life Cycle Assessment; steel; structures, concrete and steel

1 Introduction

1.1 Background

The building industry and the use of buildings account for a considerable proportion of man's total impact on the natural environment. In order to make an inventory and assessment of the total environmental impact for the whole life cycle of a building, information and data concerning materials, building components and building processes are necessary. Tools and methods for assessing this kind of environmental impact are urgently needed today. The methods should be so transparent that the user can determine the basis on which the results have been obtained. For some decision areas, LCA (Life Cycle Assessment) is a useful tool for the environmental analysis and assessment of buildings and building materials. There is, however, a need to adapt the method of LCA for application to these areas.

There has been ongoing collaboration in the cement industry in Sweden, Norway and Finland for some years to improve the environmental performance of products and processes. This study, which is part of this work, was performed at Chalmers University of Technology in Sweden in close co-operation with the Nordic building material industry. Full data and other detailed information concerning the case study is available in [1].

Internationally, several building-related LCAs have been performed, some of them on the system level of structural elements [2,3,4,5]. Among these studies, the need to create systems models above the building material level to assess the environmental consequences of using alternative building elements and frame structures is generally recognised. There are considerable differences between the studies concerning what structural assemblies are included in the functional unit, what types of structures are compared, what life cycle steps are taken into account, what environmental loads are addressed, how the impact assessment and interpretation of the results is performed, etc. so that the results and conclusions are therefore not easily compared. Several studies show that the impact from the use phase weighs heavily when taken into account. As a rule, problems concerning occupational safety and health are omitted. The results from the two studies that include a comparison of concrete and steel frame structures [2,3] indicate, in a life cycle perspective, that there is little difference between the addressed environmental loads of these two frame structures.

1.2 Aims and objectives

The principal aims and objectives of the study were to learn about the environmental impact of structural concrete and steel frames in buildings throughout the life cycle, to assess and compare this environmental impact by using the method of LCA, to create a computerised model for environmental assessment of frame structures that may be used as a tool

Int. J. LCA 3 (4) 216 – 224 (1998)

for improvement analysis, and, finally, to study what methodological problems arise specifically when performing an LCA for such a complex structure as a building frame. As there were many possible users of the results, the purpose was rather to describe the environmental impact of an existing product system than to investigate consequences of a specific change or action.

1.3 Methodology

LCA is a method for analysing and assessing the environmental impact of a material, product or service throughout its entire life cycle, usually from the acquisition of raw materials to waste disposal. SETAC is an international organisation which has taken on the role of developing and harmonising LCA methodology. International standardisation work on LCA takes place under the auspices of the ISO [6]. The paper is largely structured according to the SETAC guidelines [7] on what is to be included in an LCA. Readers wishing to study LCA methodology in greater depth are referred to [6,7,8,9,10].

2 Goal Definition and Scope

A representative segment of offices and dwellings with several storeys was analysed from an environmental point of view. Seven frame cases were studied:

1. In-situ cast concrete frame (office)
2. In-situ cast concrete frame (dwelling)
3. Precast concrete frame (office)
4. Precast concrete frame (dwelling)
5. Steel/concrete frame (office)
6. Steel/concrete frame (dwelling)
7. Steel/steel frame (dwelling).

The functional unit, i.e. the basis for comparison, was defined as one average square meter of floor area during the lifetime of a building, based on Swedish building standards. Frame construction and supplementary materials needed to make each frame case deliver an equivalent minimum function were included. The parts of the building that are load-bearing varied between the frame constructions, and thus there was also variation among the frame constructions regarding what supplementary materials were included in the functional unit. For example, the load-bearing part of the in-situ cast concrete frame is the internal wall while for the precast concrete frame it is the external wall. Hence, a supplementary external wall was included in the functional unit for the in-situ cast concrete frame and supplementary internal walls in the functional unit for the precast concrete frame. The representative segment of a building on which the functional unit was based is shown in **Figure 1**. The study was delimited by the following main conditions:

- Chosen frame designs should be representative of present-day building technology in the Nordic countries.
- Data account, if possible, for production and use in Sweden, and describe the contemporary environmental impact. The aim was to describe the average situation rather than today's best available technology.
- Both horizontal and vertical construction elements were included.
- The heat resistance value (U-value) of the external wall was set to 0.30 W/m^2 °C for offices and 0.25 W/m^2 °C for dwellings.
- It was assumed that all frame structures studied have the same average lifetime, i.e. that the lifetime of a building is generally determined by issues other than choice of frame construction.
- The study was confined to effects on the external environment. Parameters included, as far as possible, were use of raw materials, energy use, emissions to air, emissions to water and waste generation. For practical reasons, the study focused on those parameters which can be added throughout the life cycle of a product. Some issues not included were infrastructures, accidental spills, personnel-related effluents, human resources, work environment, indoor climate, noise and odour.
- Electricity use was accounted for as the amount of electricity used and the environmental loads of electricity production were thus omitted. When this study was performed, the availability of quantitative LCA data was limited for the Swedish electricity production which is mainly based on nuclear and hydropower.
- Three quantitative assessment methods were used: The *Environmental Priority Strategies in product design (EPS) method*, developed in Sweden [11], the *Environmental Theme Method*, developed in the Netherlands [8] and adapted to Swedish conditions [12], and the *Ecological Scarcity Method*, developed in Switzerland [13] and adapted to Swedish conditions [12].
- No sensitivity analysis employing statistical measures of uncertainty was performed. However, some data with a high degree of uncertainty, and with major influence on the results, was identified and then dealt with through calculating several possible scenarios. This was the case when deciding what parts of the environmental impact during the building's service life could be related to the functional unit, and whether the demolition waste was used as filling mass or landfilled.
- It was beyond the scope of the study to quantify the effects of potential improvements.

3 Calculation Model

Flow charts were used to describe the life cycle of each frame construction. A hierarchical calculation model was developed (→ *Fig.* 2) using a computer program called LCAiT (LCA

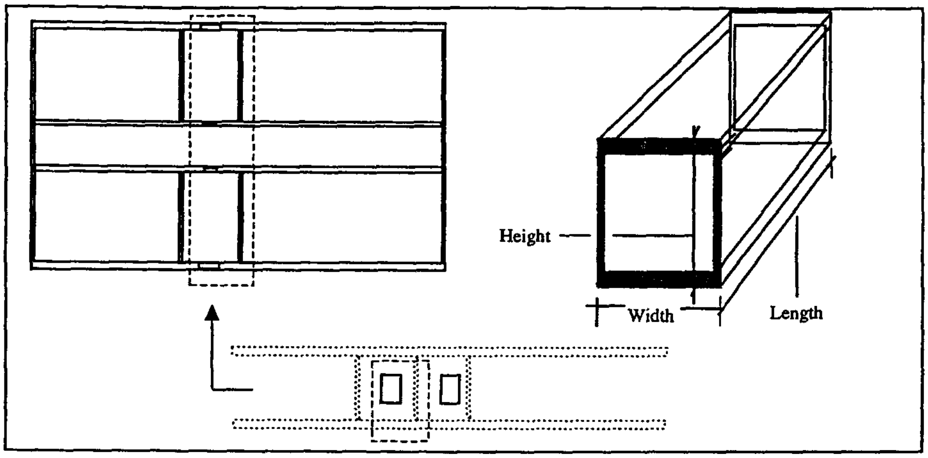

Fig. 1: Representative segment. The functional unit consists of one average horizontal square meter of the segment

Inventory Tool). Also, for each specific process step, allocated data on material and energy flows was presented separately in data files. The calculation model was structured into four levels: raw materials, building materials, building components and frames. On the building component level, a data structure generally used in the Swedish building industry could be used [14]. The inventory data could thus be presented in a pedagogical structure, suited to the improvement analysis intended to be performed by the commissioning party.

4 Inventory Results

Data were elaborated for the environmental load of concrete and steel production and for the process steps from raw material to building site. For other materials (gypsum board, insulation, etc.) literature data were used when available. Then the environmental load (mainly related to energy use) from the building site, from use and maintenance and from the demolition and final disposal phases was assessed.

Energy requirements for and emissions from transportation were calculated by consistent application of standardised energy use and emission factors [15]. It was assumed in the calculations that all building materials become either filling mass or waste after demolition. The only exceptions were steel beams and columns that were assumed to be separated at the demolition site and recovered. A user time of 50 years was assumed in the calculations. The environmental load was calculated in relation to the functional unit, and the inventory results were presented and evaluated, distributed into three life cycle steps (→ *Fig. 2*):

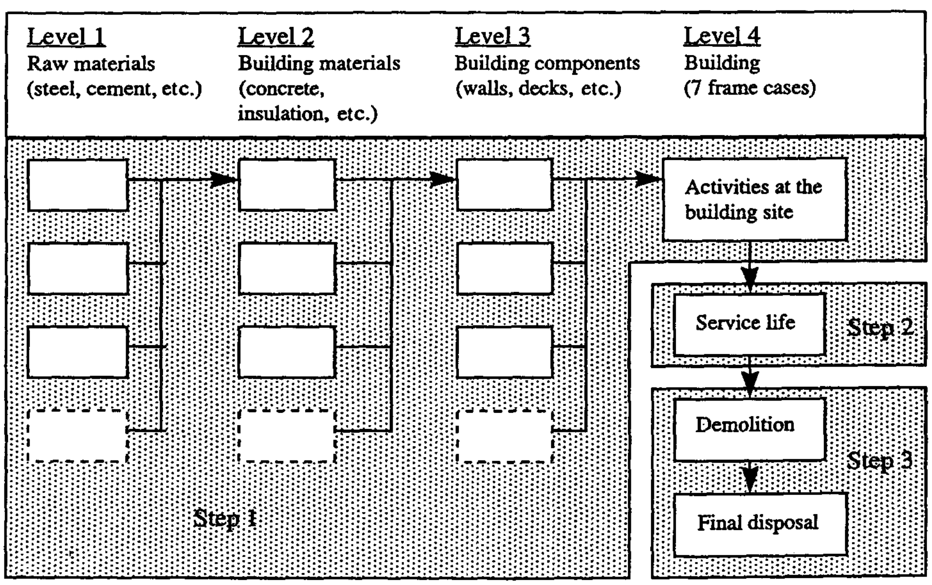

Fig. 2: Structure of the data model used in the calculations. Level refers to level of complexity, step refers to the main steps in the life cycle (Step 1: Building production from cradle to gate, Step 2: Service life, Step 3: Demolition and final disposal)

Step 1: Building production from cradle to gate (from raw materials extraction to building site)
Step 2: Service life
Step 3: Demolition and final disposal.

A selection of the inventory results is accounted for here. The results, over the life cycle, indicate that most material resources are used for building production from cradle to gate (→ *Fig. 3*). Most of these resources are non-renewable, but the supplies are generally abundant for the foreseeable future. Of the main resources used, only supplies of fossil materials are scarce or limited.

Figure 4 accounts for the energy use of building production from cradle to gate (Step 1). Fossil fuels and electricity are the main energy sources, and there is no use of renewable fuels. Use of fossil fuels as an energy source is related to cement and concrete production, whereas the use of fossil fuels primarily as raw material (coal/coke) is closely associated with the amount of steel used in a frame. Use of electricity was accounted for as direct use. The efficiency of average Swedish electricity production is estimated to be 54% [16].

In **Figure 5**, some emissions to air and water (CO_2, NO_x, SO_x and COD) and wastes occurring in building production

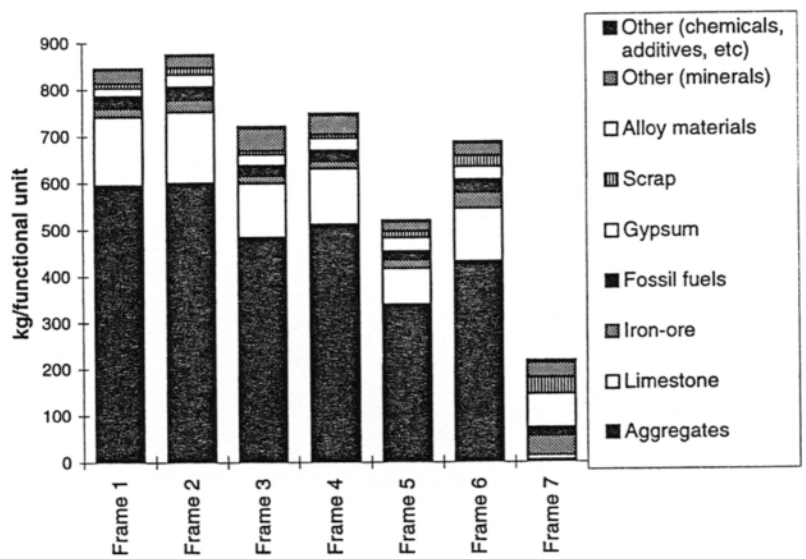

Fig. 3: Use of material resources per functional unit for building production from cradle to gate (Step 1). Aggregated parameters. Fossil fuels included

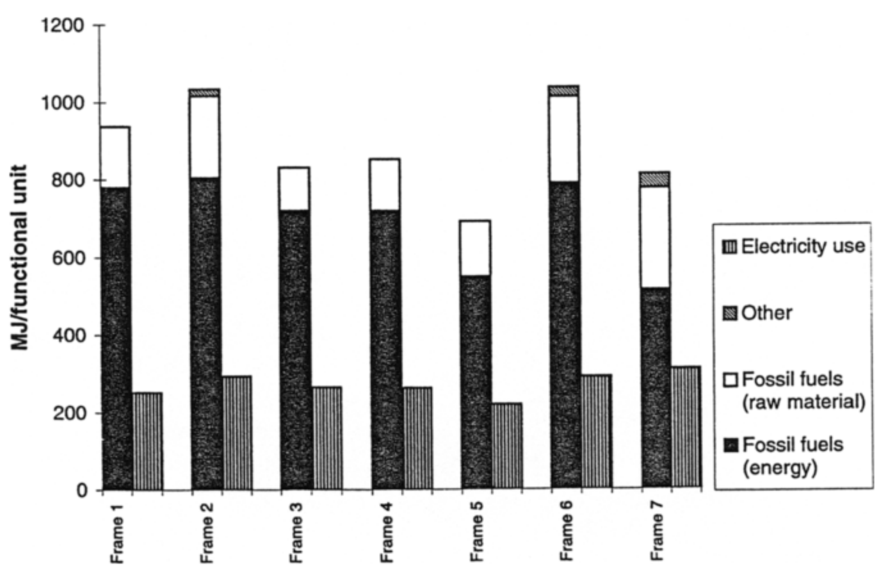

Fig. 4: Energy use per functional unit for 7 frames for building production from cradle to gate (Step 1). Feedstock energy of fossil materials used primarily as raw materials included

from cradle to gate (Step 1) are shown. CO_2 emissions occur both as process emissions from cement production and from use of fossil fuels, while NO_x and SO_x emissions are mainly energy related. COD emissions to water occur both in production of fossil fuels and as a process emission, especially from plasterboard production. The non-hazardous waste consists mainly of building, industrial and mineral waste (demolition waste does not belong to this step). Most of the hazardous waste occurs during the production of pre-stressing wire. It mainly consists of used bate acids (diluted sulphuric acid with dissolved metals, primarily iron). Although classified as hazardous waste, both bate acids and metals are reused in industrial processes after treatment.

indoor temperature is allowed to fluctuate. Technical support systems used for hot water production, lighting, ventilation, etc. are not directly related to choice of frame construction, although choice of frame may restrict what technical support systems may be chosen. Also, variations in operating energy use connected to activities may not be directly linked to choice of frame construction. Thus, only the environmental loads from maintenance and from heat losses through the external walls may be directly linked to the functional unit during service life. For the sake of comparison, the average operating energy use for offices and dwellings based on Swedish statistics and the potential energy saving related to thermal storage in the frame for some defined circumstances

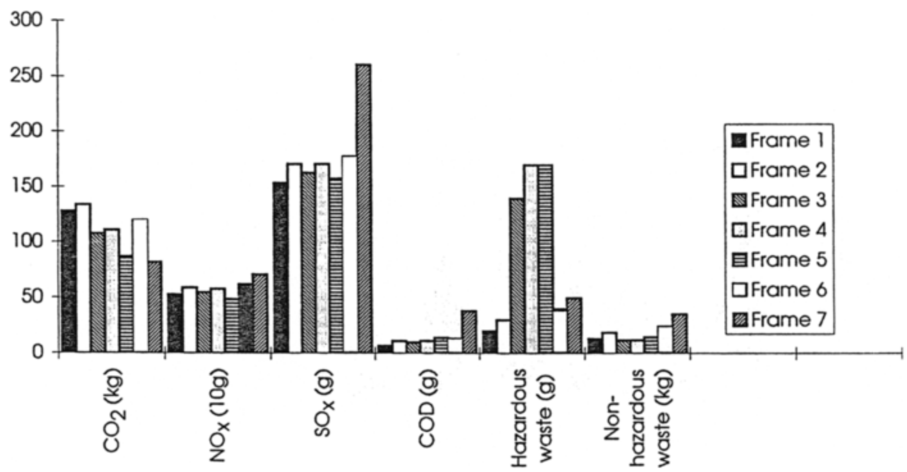

Fig. 5: Emissions to air, emissions to water and waste generation per functional unit for 7 frames for building production from cradle to gate (Step 1). Selected parameters

During service life (Step 2), the main environmental impact is related to energy use, including energy related emissions to air and use of fossil resources. The quantity of operating energy used varies mainly with what activities will be carried out in the building, what technical support systems have been chosen and also with the choice of building construction. Maintenance and reconstruction of facilities in the building account for only a minor part of the energy use during service life. The following parts of the operating energy use and other activities during service life could be directly related to choice of frame construction:

- Maintenance (replastering of facades, rebuilding of internal walls in office buildings)
- Energy losses owing to heat transmission through the external walls, as these energy losses are bound to vary with the heat resistance value (U-value) of the wall.

Thermal storage in the frames may decrease the energy use during service life, but can only be fully assessed when studying the whole building. Among conditions for thermal storage to take place are sufficient constructional mass for the heat to be stored in, that excess energy is available and that the are also presented. The inventory results for service life were organised and presented as follows:

Step	Definition
2a	Environmental load attributable to maintenance, comprising the environmental load from rebuilding of internal walls in offices and maintenance of facades.
2b	Environmental load attributable to energy losses from heat transmission through the external walls. Step 2a is included.
2c	Environmental load attributable to statistical energy use. Step 2a is included.
2d	Environmental load attributable to statistical energy use, taking into account the effects of thermal storage in the internal building elements. Step 2a is included.

The energy use stands for the dominating environmental loads during service life, and thus only energy data are presented for this phase (→ *Fig. 6*). Since an equivalent U-value was used for offices and dwellings, the energy losses

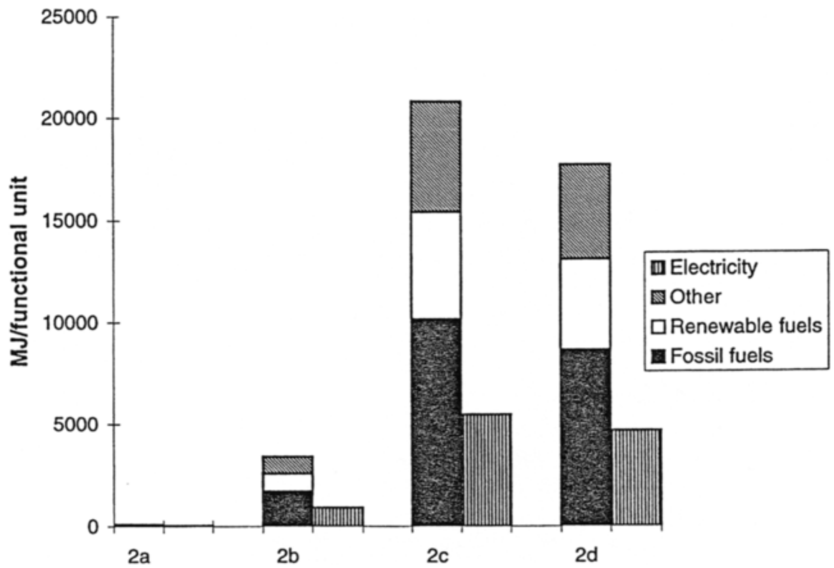

Fig. 6: Energy use per functional unit from service life (Step 2) for frame 1. A user time of 50 years is assumed. 2a: Maintenance, 2b: Energy losses from heat transmission through the external walls, 2c: Statistical energy use, 2d: Statistical energy use, taking into account the effects of thermal storage in the internal building elements

due to heat transmission through the external walls would be equivalent for all offices and all dwellings. As an example, Figure 6 shows the energy use of service life for frame 1.

For the statistical energy use, electricity and fossil fuels are the main energy sources. The energy use from the maintenance (Step 2a) was insignificant compared with the steps where heating energy was involved. The energy use considered to be directly related to the frame (Step 2b) was far below the total statistical energy use (Step 2c). The energy use that under defined conditions may be saved by thermal storage in the frames (Step 2d) was of the same order of magnitude as energy losses through the external walls (Step 2b). The total statistical energy use (Step 2c) far exceeded the energy use during the other life cycle steps (building production from cradle to gate, demolition and final disposal).

During demolition and final disposal (Step 3), raw material use, energy use and emissions to air and water were all less than in previous parts of the life cycle (Steps 1 and 2), although the quantities of demolition mass were almost equal to the quantities of materials used (→ *Fig. 3*). It is probable that mass from the demolition process is used to a large extent as filling mass and thus is not defined as waste. If it were defined as waste instead, quantities from demolition and final disposal would far exceed waste generation from previous life cycle steps. The steel frame gives rise to a considerably lower amount of demolition mass than the other frames. There is a lack of detailed enough data today regarding the environmental load of final disposal of building wastes.

5 Impact Assessment Results

An impact assessment was conducted to identify what inventory parameters were most important from the environmental point of view. Impact assessment involves aggregating the environmental profile (i.e. the environmental *load*) into more effect-related measures which may be further weighed together, ultimately into a one-dimensional index. The procedure consists of the following steps: classification, characterisation and valuation/weighting. Several methods are available for environmental impact assessment [10], and this is an area still under development. The valuation/weighting step can not be based on traditional natural sciences, and political, ethical and administrative considerations and values are therefore used [10]. Thus, subjective choices have been made within each of the available methods and, as a consequence, the environmental problems focused on differ between them. In this study, three quantitative assessment methods, each resulting in one single value, were used:

- The *Environmental Priority Strategies in product design (EPS) method*, developed in Sweden [11]. The evaluation is based on willingness to pay within the OECD countries to restore the five protected values to a reference condition: biological diversity, human health, production, aesthetic values and natural resources.
- The *Environmental Theme Method*, developed in the Netherlands [8] and adapted to Swedish conditions [12]. Inventory data are converted to contributions to known environmental problems, defined as environmental themes, and then weighted against one another on the basis of Swedish environmental policy objectives for 1995.
- The *Ecological Scarcity Method*, developed in Switzerland [13] and adapted to Swedish conditions [12]. Ecological scarcity is defined as the ratio between total environmental impact and the critical impact within a geographically defined area. Swedish environmental policy objectives were primarily used as a measure of the critical impact.

Figures 7 to 9 show what environmental parameters weigh heavily for building production from cradle to gate (Step 1) when using these three methods, and what inventory parameters are the main contributors to the total impact. A high value indicates a high potential contribution to the environmental effects.

When applying the EPS method (→ *Fig. 7*), alloy materials, CO_2 emissions and use of fossil fuels account for the absolutely largest part of the impact. The method puts emphasis on use of scarce resources, and as supplies of alloy metals are generally more scarce than supplies of iron ore, these metals get much higher scores than iron ore and scrap, although the latter are used in higher quantities. Use of fossil resources is also highly scored by the EPS method. CO_2 emissions are highly valued because of their contribution to global environmental effects like the greenhouse effect. As a consequence of the high score for alloy materials, the frames using the most steel also get the highest total value.

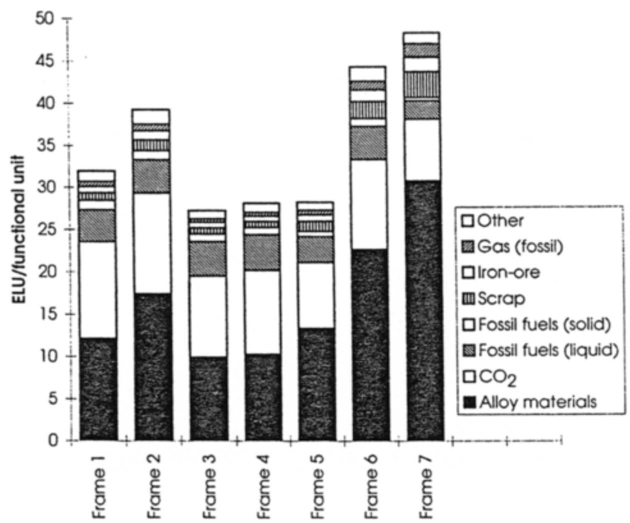

Fig. 7: Environmental impact per functional unit for seven frames for building production from cradle to gate (Step 1) when applying the EPS method

When the Environmental theme method (→ *Fig. 8*) is applied, the total impact from cradle to gate is more equal between the frames than when the EPS method is applied. The most important parameters – NO_x, CO_2, electricity and SO_x – are all related to energy production and use. These parameters are all ranked as being important, according to environmental policy targets. Generation of mineral waste also influences the results. This method has no scores for material use other than energy resources and land use, but most indices have to do with emissions to air and water. The composition of parameters contributing to the total impact is similar between all frame cases.

In Figure 9, the total environmental impact per functional unit when applying the Ecoscarcity method is described.

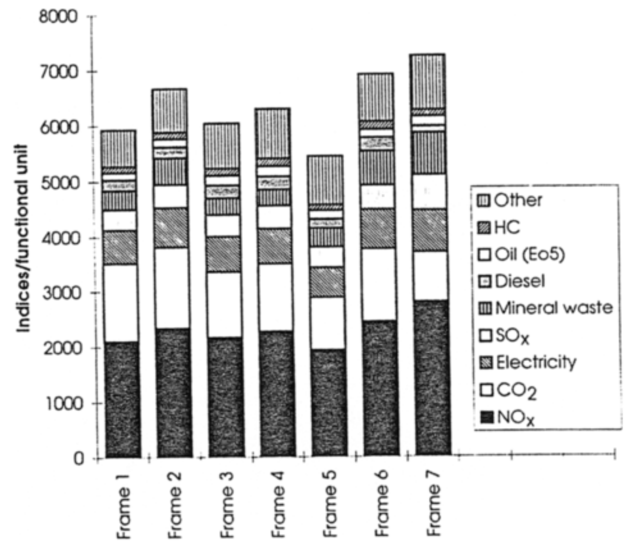

Fig. 8: Environmental impact per functional unit for seven frames for building production from cradle to gate (Step 1) when applying the Environmental theme method

Some parameters with a high contribution have to do with energy production and use (such as NO_x and CO_2), but waste parameters are also highly scored. As emissions of metals are given a great emphasis in this method, the contribution of metal emissions is notable. Frames 3 to 5 have a higher contribution of hazardous waste than the other frames. As hazardous waste is very highly scored by the method, quantities needed to give high scores are low. The Ecoscarcity method does not take resource depletion into account, except energy use which is assessed with the same index regardless of what energy source is used.

When comparing the results presented in Figures 7 to 9, it is seen that what frame has the highest environmental impact from cradle to gate (Step 1) differs between the methods. According to the EPS method, the steel frames have a slightly higher environmental impact than the other frames, but the span between highest and lowest values is not significant enough for the other two methods to draw any conclusions about what frame construction has the lowest environmental impact. According to Figures 7 to 9, parameters that generally weigh heavily during building production from cradle to gate (Step 1) are use of fossil fuels, electricity, CO_2, SO_x, NO_x, alloy materials and waste. What parameter is most important depends on what assessment method is used.

Building production from cradle to gate (Step 1) has about the same contribution as maintenance and heat losses through external walls during service life (Step 2b), whereas demolition and final disposal (Step 3) has a considerably lower impact, assuming that all demolition materials are used as filling mass and are not defined as waste. If the demolition mass instead were defined as waste, the environmental impact from demolition and final disposal (Step 3) would be equal to and sometimes exceed the impact from earlier steps

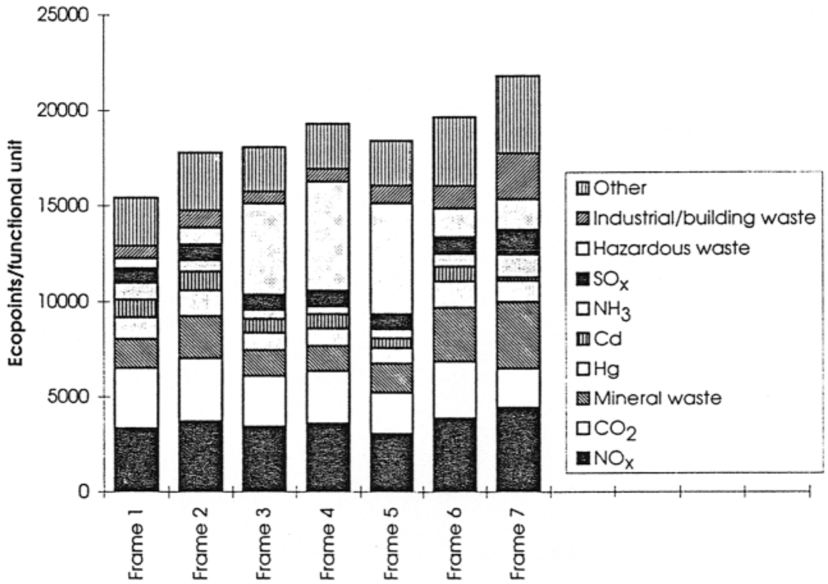

Fig. 9: Environmental impact per functional unit for seven frames for building production from cradle to gate (Step 1) when applying the Ecoscarcity method

of the life cycle, according to two of the three methods used. Thus, the results indicate that recycling of demolition mass, if only as filling mass, is important in terms of reducing the impact of buildings over their life cycle. Since the amounts of building waste produced may influence the final results substantially, the environmental assessment methods used need to further elaborate and specify indices for waste. The impact of total statistical energy use during the service life of the building (Step 2c) greatly exceeds the impact from other parts of the life cycle (Steps 1 and 3) when assuming a user time of 50 years.

6 Discussion and Conclusions

The results from the inventory analysis and impact assessment indicate that:

- Parameters that weighed heavily in the impact assessment were use of fossil fuels, CO_2, electricity, SO_x, NO_x, alloy materials and waste, depending on what method was used.
- Building production from cradle to gate has about the same contribution as maintenance and heat losses through external walls during service life, whereas demolition and final disposal has a considerably lower impact, assuming that all demolition materials are used as filling mass and are not defined as waste.
- The impact of total statistical energy use during service life largely exceeds the impacts from other parts of the life cycle, when assuming a user time of 50 years. However, only a small part of this impact is directly related to choice of frame construction.
- Frames should preferably be constructed so that the energy use during service life is decreased as far as possible, i.e. by avoiding heat transmission through external walls and enabling thermal storage when possible.

A computerised model for environmental assessment of frame structures was created by using the method of LCA. It was found that a data structure already applied in the Swedish building industry could be used. Because the model consisted of several levels and described a functional unit of high complexity, interpretation of the results became complicated and time consuming with the tool used (see below).

Looking at LCA history, many early LCAs were conducted for products with a limited number of components and functions. In this study, because so many components are part of the functional unit, more than one hundred parameters were included in the inventory. Some experiences from conducting LCA on a more complex system structure with several hierarchical levels are that:

- The risk of mistakes increases with the degree of complexity of the functional unit, and it also becomes more difficult to get consistency when applying chosen system boundaries.
- It is not obvious what questions are to be posed and answered by the analysis as the number of involved data providers and users of the results increases, or rather, the number of possible questions increases. With many users of the results, it becomes unclear for what parts of the life cycles average data are to be used rather than specific data.

- Only the impact appearing on or below the system level of the functional unit may be included in an environmental assessment, as impact belonging to a more complex system also depends on various conditions beyond defined system boundaries. For example, not all of the statistical energy use during the service life of a building is directly related to the design of the building frame but depends on circumstances such as choice of heat distribution and ventilation system of the building and the activities going on in the building. On the other hand, less information, and perhaps less relevant information, is conveyed when communicating only a smaller part of the energy use during service life which is directly related to the functional unit.
- A very high degree of transparency is necessary when studying a complex system structure, which means that presentation of the results is demanding because they are so comprehensive.
- Testing the effects of exchanging inventory data, changing system boundaries, etc. becomes a complicated and time consuming task when studying a functional unit of high complexity. Also, because the final results were based on inventory data aggregated on four levels where the lowest level (cement and steel production) already constituted an aggregation of a process tree, results obtained were not easily related to the specific process steps most responsible for the impact found in the impact assessment. The successive aggregation of data necessary to enable interpretation of the final results made it difficult to find the "hot spots" in the system, i. e. to find out where improvements are most urgent. These problems would partly be solved by using more appropriate computer software.

Acknowledgements

This project was part of a Nordic co-operation project, initialised and partly financed by the cement industry in Sweden, Norway and Finland. A number of people from the building industry contributed by gathering information and reading and commenting on the drafts of the final report. The authors wish to thank the Nordic cement industry and other data providers from the building industry who have contributed useful information.

7 References

[1] Björklund T, Jönsson Å, Tillman A-M.: LCA of Building Frame Structures. Environmental Impact over the Life Cycle of Concrete and Steel Frames. Report 1996:8, Technical Environmental Planning, CTH (Chalmers University of Technology), Göteborg, 1996

[2] Amato A, Eaton K J.: A comparative life-cycle assessment of steel and concrete framed office buildings. Proceedings of Second International Conference on Building and the Environment, CIB TG8, June 9-12, Paris, 1997

[3] Life-Cycle Energy Use in Office Buildings. The Environmental Research Group, School of Architecture, UBC (University of British Columbia), Forintek Canada Corp., Vancouver, 1994

[4] Petersen E H.: Livscyklusvurdering af bygningsdele. SBI report 272, SBI (Statens Byggeforskningsinstitut), Hoersholm, 1997

[5] Erlandsson M.: Environmental Assessment of Building Components. Licentiate of Engineering Thesis, TRITA-BYMA 1995:1, KTH (Royal Institute of Technology), Stockholm, 1995

[6] ISO 14040. Environmental management - Life cycle assessment - Principles and framework. First edition, TC 207 / SC 5, 1997

[7] Consoli F (ed.) et al.: Guidelines for Life-Cycle Assessment: A 'Code of Practice'. SETAC (Society of Environmental Toxicology and Chemistry), Brussels/Pensacola, 1993

[8] Heijungs R (ed.) et al.: Environmental life cycle assessment of products - Backgrounds and Environmental life cycle assessment of products – Guide, CML, TNO, B&G, Leiden, 1992

[9] Life-Cycle Assessment: Inventory Guidelines and Principles. EPA/600/R-92/036, EPA (Environmental Protection Agency), Cincinnati, 1992

[10] Lindfors L-G et al.: Nordic Guidelines on Life-Cycle Assessment. Nord 1995:20, Nordic Council of Ministers, Copenhagen, 1995

[11] Steen B , Ryding S-O.: The EPS Enviro-Accounting Method. An application of environmental accounting principles for evaluation and valuation of environmental impact in product design. IVL report B 1080, IVL (Swedish Environmental Research Institute), Göteborg, 1992

[12] Miljömässiga skillnader mellan återvinning/återanvändning och förbränning/deponering. CTH, CIT, IVL, SI. Reforsk FoU nr 79, 1993

[13] Ahbe S, Braunschweig A, Muller-Wenk R.: Methodik für Oekobilanzen auf der Basis ökologischer Optimierung. Schriftenreihe Umwelt nr 133, BUWAL, Bern, 1990

[14] Wermelin I.: Aktiv kostnadskalkylering med hjälp av BSAB-systemet. AB Svensk Byggtjänst, Stockholm, 1983

[15] Tillman A-M et al.: Packaging and the Environment. SOU 1991:77, Allmänna förlaget, Stockholm, 1991

[16] Boustead I.: Eco-balance methodology for commodity thermoplastics. PWMI, Brussels, 1993

Received: May 15th, 1998
Accepted: June 25th, 1998

See also the Int. J. LCA 1 (2) 90-96 (1996)

Life Cycle Analysis with Ill-Defined Data and its Application to Building Products

Jean-Luc Chevalier, Jean-François Le Téno

In contradiction with the flow accuracy requirement of the classical LCA model, most LCA data cannot be represented by an accurate value because they loose realism in the process. It is particularly true with building products' data. Intervals are introduced to model such data, thus allowing LCA calculations to get rid of flow accuracy. Thus, interval calculation techniques for LCA are developed and the benefits from a replacement of classical LCA algorithms with these techniques are analyzed.